A Mobile Visual Analytics Approach for Law Enforcement Situation Awareness

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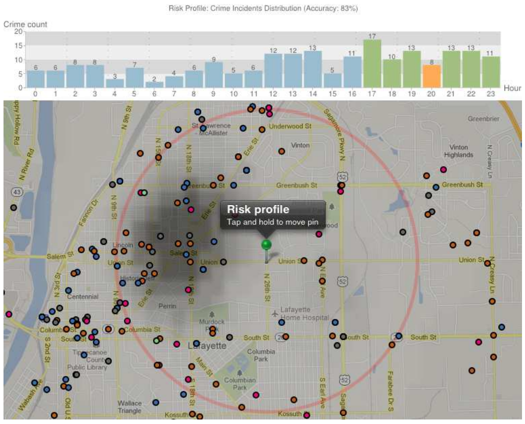
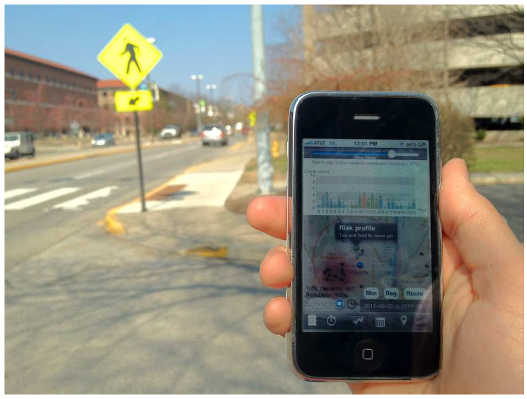


(a) Risk profile tools give time- and location-aware assessment of public safety using law enforcement data.



(b) The mobile system can be used anywhere with cellular network coverage to visualize and analyze law enforcement data. Here, the system is being used as the user walks down a street.

Figure 1: Mobile crime analytics system gives ubiquitous and context-aware analysis of law enforcement data to users.

Abstract

The advent of modern smartphones and handheld devices has given analysts, decision-makers, and even the general public the ability to rapidly ingest data and translate it into actionable information on-the-go. In this paper, we explore the design and use of a mobile visual analytics toolkit for public safety data that equips law enforcement agencies with effective situation awareness and risk assessment tools. Our system provides users with a suite of interactive tools that allow them to perform analysis and detect trends, patterns and anomalies among criminal, traffic and civil (CTC) incidents. The system also provides interactive risk assessment tools that allow users to identify regions of potential high risk and determine the risk at any user-specified location and time. Our system has been designed for the iPhone/iPad environment and is currently being used and evaluated by a consortium of law enforcement agencies. We report their use of the system and some initial feedback.

Keywords: Mobile visual analytics, situation awareness, public safety

Index Terms: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.8 [Computer Graphics]: Applications—Mobile Visual Analytics

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1 Introduction

In 2010, the number of handheld devices reached a staggering volume of 4 billion devices globally [9]. With a large and diverse user base, it is the only truly universal computational platform today. With this global explosion in the usage of modern smartphones and handheld devices, users now have more connectivity to the digital world and the ability to ubiquitously ingest data and transform it into knowledge that enables them to comprehend a situation better and make more effective decisions. However, challenges associated with the data processing, exploration and analysis on a mobile platform are becoming prominent due to the increasing scale and complexity of modern datasets and limited screen space of mobile devices. These challenges are being addressed by the emerging field of visual analytics [40]. Visual analytics in the mobile domain utilizes state-of-the-art mobile devices and provides users with the ability to effectively and interactively analyze large and complex datasets on-the-go; thereby, providing analysts, in-field workers, responders, decision makers and other users insights into any emerging or emergent situation in real-time (Figure 1).

In this paper, we present a mobile visual analytics approach for solving one such problem in the public safety domain. Our work leverages the ubiquity of the mobile platform and focuses on creating an effective, interactive, client-server-based situational analysis and analytics system for the geotemporal exploration of criminal, civil and traffic (CTC) incidents. Our mobile system (Figure 1b) provides on-the-go situational awareness tools to law enforcement officers and, in the future, to citizens. Our system has been designed in collaboration with a consortium of law enforcement agencies and first responder groups and has been developed using a user-centered approach. Designing a mobile visual analytics system in this domain provides a unique set of challenges that range from identifying the in-field needs of a diverse group of end-users to understanding the applicability of a mobile solution to improve the day-to-day operations of law enforcement officers. We discuss these challenges and present our mobile solution that has the following main contributions:

- *Identifying the needs of first responders and law enforcement agencies in the mobile domain.* Our collaboration with the law enforcement agencies enables us to explore and discuss the use of our system in their day-to-day tasks at different organizational levels in the agencies.

- *Discussion of the design of a public safety mobile visual analytics solution for the first responder community.* We adapt several methods and techniques to work effectively in a mobile environment that has unique interaction methods, use cases, and objectives (e.g., risk profile, hotspot alerts, plume visualization).

2 RELATED WORK

The use of mobile devices in visual analytics has proliferated greatly over the past few years. Mobile devices should not be thought of merely as auxiliary devices for use while on the road but they are the new personal computers [9]. With the explosion of the number of users of smartphone, tablets and other mobile devices, the interest to develop visual analytic systems on the mobile platform has greatly increased. For example, work by Kim et al. [23] presents a mobile visual analytics system for emergency response cases and highlights the use of such systems in time-critical applications. However, these systems face a unique set of challenges compared to the commonly used desktop systems. Some of the main constraints of mobile systems include limited performance, small displays, and different usage environments [30, 37]. Novel methods that deal with these unique constraints are thus a must. Pattath et al. [31], for example, focus their work mainly on addressing the display and interaction area size constraint by utilizing the focus+context technique. Additionally, the development of mobile visual analytics systems provides novel use cases that traditional desktop systems cannot provide.

For a dataset of geospatiotemporal nature (data with information to geographical location and time) such as public safety data, geographic information systems (GIS) play an important role in the exploration and analysis processes in decision support environments [3]. There exist many GIS systems that provide tools to support the Exploratory Data Analysis (EDA) [41] process. Many of these systems provide a geospatial interface along with statistical tools for analysis and are usually designed to enable users to explore trends, patterns and relations among such datasets [6, 16]. For example, Andrienko et al. developed the Descartes system [5] that automates the presentation of data on interactive maps. The GeoDa system [8] also provides an interactive environment for performing statistical analysis with graphics. Many systems are also tailored to focus on specific applications in a given domain. Examples of these include GeoTime [21] and Flow Map Layout [32] that focus on tracking movements of objects in time. Other domain specific applications include traffic evacuation management [19] and urban risk assessment [24].

Similarly, GIS systems provide important support in the public safety domain [12]. In analyzing and modeling the spatiotemporal behavior of criminal incidents, Chen et al. [13], developed a crime analysis system with spatiotemporal and criminal relationship visualization tools. However, in contrast to our focus on risk assessment and situational awareness in the mobile domain, their system focuses on finding relations between datasets and is developed for a desktop environment. Moreover, there exist many web-based crime GIS tools (e.g., [14, 15, 28, 29, 33, 36, 39]). However, most of these tools offer only basic crime mapping and filtering functionalities and provide basic analytical tools to allow users to perform EDA. Also, many of these systems target casual users only. Similarly in the GIS domain, some systems also target non-GIS specialists (e.g., [4, 8]). Our system is designed to enable domain experts and, in the future, ordinary citizens explore and analyze spatiotemporal CTC incidents. Our work uses the notion of casual visualization [34], but further provides statistical tools that help users identify trends, patterns and relations within the data in the EDA process.

The ability to have situational awareness in law enforcement is essential in maintaining public safety. Situational awareness by definition [18] enables one to perceive, comprehend, and project into the future to make more effective decisions. Law enforcement officers make decisions in resource allocation and patrol planning to reduce crime, while citizens may make decisions to be at a place at any particular time. Critical to gaining awareness of a situation are the fundamental questions of where, what, and when an event/incident occurs [7]. Our mobile system, similar to many GIS tools, presents the law enforcement information in a place-time-object organization to allow for information exploration and sense-making using the different tailored views that we have developed based on the user-driven requirements of different situations.

3 REQUIREMENTS AND CHALLENGES

Our system's design was driven by the task, environment, and device factors gathered from our end users through a user-centered design approach.

3.1 Domain Analysis of Requirements

Our collaboration with local law agencies started with our work on an earlier desktop-based system [27]. Having seen the benefits of a desktop based visual analytics system in their operations, the local law agencies approached us with the idea to develop a system for the mobile platform that addresses their mobile needs. As such, we had several meetings and informal discussions about the use of such a mobile system in their day-to-day tasks to derive the system requirements.

Below, we identify the requirements of the law enforcement agencies and explore the use of such a mobile system based on our formative engagements with officers ranging from shift supervisors, patrol officers, detectives, and crime analysts.

R1: Easy operation — Mobile systems are often used ubiquitously, sometimes in less than ideal conditions. Additionally, using a mobile system in such conditions often requires users to divide attention between the system, the task they are performing, and their surroundings. Thus, the visualizations need to be easily comprehensible in a short glance and interaction should be simple and easy.

R2: On-the-go risk assessment and emergency management — Our end users emphasized the need for a mobile analytics system that would provide on-the-go risk assessment to in-field officers. Crime trends are affected by the hour-of-the-day and day-of-the-week effects, and, as such, our risk profile system factors in the current location and time of the officers to provide them with a situational awareness of their surroundings. Additionally, because our end user group included first responders, there was a need for emergency management tools in case of accidents that potentially affected a large population. As such, we provide tools that allow them to visualize the impacts of chemical spills for use in emergency and evacuation situations.

R3: Near real-time data — The shift supervisor is primarily responsible for resource planning and allocation. He needs to have access to the most recent data and look at all the CTC incidents from the prior and current day to prepare for the shift change briefing and roll call. Thus, we design the mobile system on a server-client architecture that centralizes the entire data on the server, which is always kept up to date. Based on recommendations made by our end-users, the CTC data is currently acquired four times a day and put in to our database server which allows the data to be up to date before a patrol shift change and during patrol.

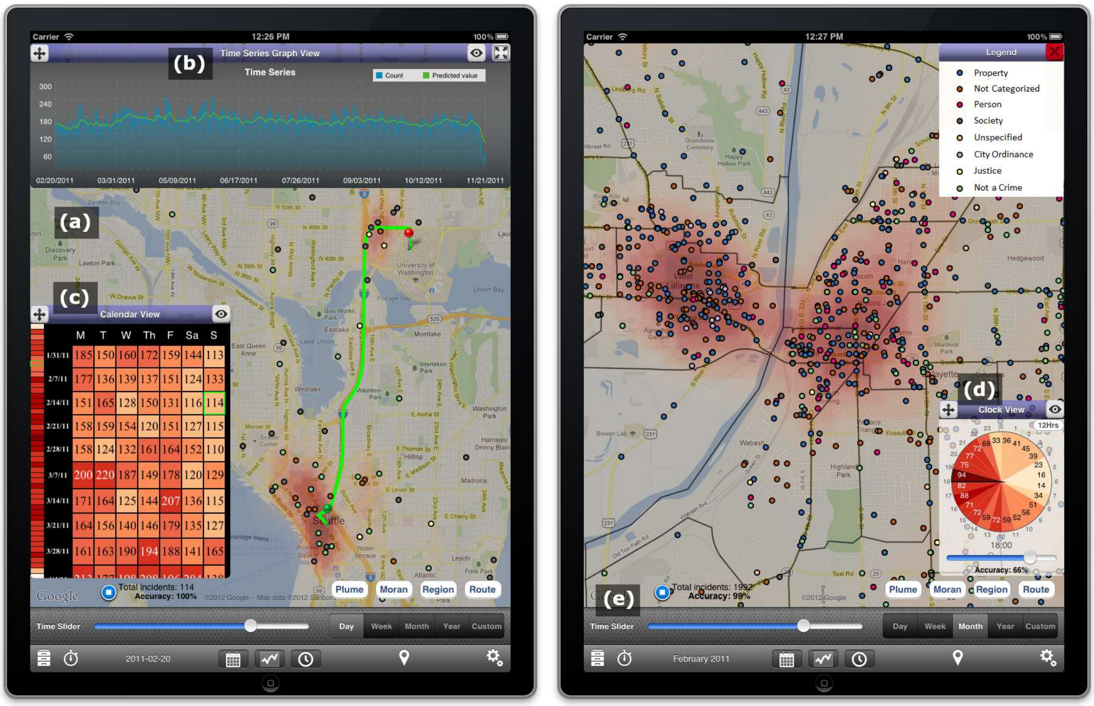


Figure 2: A screenshot of our mobile visual analytics law enforcement system. (left) Visualizing all CTC incidents for the city of Seattle, WA, USA on February 20, 2011. The map view (a) plots the incidents as color-coded points on a map (the legend for the points has been shown in the top-right window). The interactive time series view (b) plots the incident count over time with the estimated weighted moving average (EWMA) control chart overlaid. The bottom-left image (c) shows an overview+detail calendar view of the CTC incidents. (right) Visualizing all CTC incidents for Tippecanoe County, IN, for the month of February 2011. The county's census tracts have been overlaid on the map. The bottom right image (d) shows the interactive clock view to provide an hourly view of CTC incidents for the month selected. The interactive time slider (e) allows users to scroll through time and offers various temporal aggregation levels.

R4: Trend analysis and visualization — During shift briefings, shift supervisors discuss the current crime trends with patrol officers and review, for example, what has been happening over last week, day, this day last week, and so far today. They use this information for tasks including planning their patrols and deciding on what they should be on the lookout for. This is also important for detectives and crime analysts to be able to see the patterns of specific crimes over space and time. Interactive visualization of CTC trends over time is thus an important task required for the mobile system.

R5: Mobile information — The shift supervisors typically use paper print outs of the incidents that happened the previous day on a map during shift briefings to point out certain incidents of interest and show their geospatial trends. We identify that the need to offload information from a workstation to something a person can carry around (e.g., paper) is essential and that the person must be able to explore the information (they may carry multiple print outs of the map showing different information).

3.2 Mobile Challenges

Today, tasks that were once only done commonly using desktop computers can now be done using devices that can fit into a pocket [9]. But developing such a system brings about unique foci, tasks, goals, and constraints. In the following paragraphs, we discuss how some of these constraints affected the final design of our mobile system.

C1: Different task and user intent — Due to the form factor of mobile devices, certain tasks are better done on mobile devices than on desktop workstations. For example, long-term risk assessment and resource allocation are usually done using desktop workstations due to better hardware and screen space for advanced analytics. On the other hand, mobile devices are often used when officers are away from their workstations, or when they want to get a quick access to the data and focus on rapid situation assessments.

C2: Different usage environments — As briefly discussed above, the usage conditions of these systems also differs in that desktop systems are often used in a controlled office environment; whereas, mobile systems are more geared for use on-the-go. For law enforcement officers working in the field, our system is highly beneficial in providing them with tools to increase their situational awareness within their areas of responsibility [17]. Additionally, using such a mobile system out in the field introduces new challenges in that it requires the officers to have divided attention between their surroundings and the system, thereby stressing the need of having views that are intuitive and easy-to-read. As such, our system makes use of casual visualization [34] concepts in addressing these issues.

C3: Limited computing resources — The limited physical size imposed on mobile devices, which restricts their hardware capability such as computing power, memory, display area, and input capabilities due to miniaturization also limits the device performance. Speed is a key feature that users look for when performing EDA, especially because mobile systems are often used in time-critical situations. For example, officers may use this system as they respond to dispatch or emergency calls; and citizens may want to get a quick check of the safety around their area as they walk to their office. With our mobile system, we choose to determine a default data size limit (the number of incidents to load) depending on the device used and the network to guarantee an interactive performance. In this case, the most recent incidents are chosen and shown using the system.

C4: Limited/varying display and interaction area — Device fragmentation in terms of display area was another key factor in the system design process. The screen of a smartphone can only display a fraction of what is displayable on a tablet's screen (e.g., compare the iPhone's 3.5-inch screen to the iPad Mini's 7.9-inch and iPad's 9.7-inch screens). Additionally, interaction also becomes an issue where users would get a richer experience using the iPad's bigger interaction area on its touchscreen as opposed to the small touchscreen on the iPhone [20]. We thus designed the system to be context-aware and behave differently based on the device used.

C5: Security — One of the main benefits of having a risk assessment system on the mobile platform is its ubiquity. The system can be used by law enforcement agencies in situ while responding to dispatch or emergency calls. This increases the risk of having the device misplaced or stolen and thus the risk of having sensitive data falling into the wrong hands. Being used in the public, the system is also more susceptible to being a target of data sniffing. To ensure data confidentiality, we use a secure protocol to transmit encrypted data to the end-devices. We also utilize secure authentication services to authenticate the user logging on to the database in order to ensure the data is protected in case the device is misplaced.

4 Mobile Visual Analytics Environment for First Responders and Law Enforcement

Our mobile visual analytics system provides users with an overview of public safety data in the form of criminal, traffic and civil (CTC) incidents. It comprises a suite of tools that enables a thorough analysis and detection of trends and patterns within these incident reports. Our system has been developed for visualizing multivariate spatiotemporal datasets, displaying geo-referenced data on a map, and providing tools that allow users to explore these datasets over space and time (*R2*). We further provide filtering tools that allow users to dynamically filter their datasets. Our system also incorporates linked spatiotemporal views that enhance user interaction with their datasets.

Figure 2 shows two snapshots of our system. Figure 2 (left) shows all CTC incidents for the city of Seattle, WA, USA occurring on February 20, 2011, and Figure 2 (right) shows the CTC incidents for Tippecanoe County, IN, USA occurring in the month of February 2011. The main view of the system is the map view (Figure 2(a)) that provides users with the ability to plot the CTC incidents as color-coded points on the map (Section 4.3).

With temporal data, the system allows for visualization using several views, namely the time series graph view (Figure 2(b)), the calendar view (Figure 2(c)), and the clock view (Figure 2(d)). The time series graph view allows users to visualize the temporal aspect of the incident data using line graphs and model the data for abnormal event detection. The calendar view [43] lays the temporal data in the format of a calendar, allowing users to visualize the weekly and seasonal trends among the CTC incidents. The clock view, on the other hand, allows users to visualize the hourly distribution of the CTC incidents. A time series slider (Figure 2(e)) is provided to allow users to scroll in time, updating all linked views dynamically. Furthermore, our system also provides users with risk profile tools that allow them to dynamically assess the risks associated with their neighborhoods and surroundings.

4.1 Public Safety Data

Our system was developed using CTC data collected by a consortium of law enforcement agencies in our local county and from publicly available data [38, 39]. Each report entered into the database consists of, among other fields, the date and time of when the incident was reported, the time range between which the incident was thought to have occurred (e.g., in case of burglaries), the geolocation and the charges associated with the incident. Additionally, we provide multiple aggregation levels to group the different crime incidents. Our system provides support for the Uniform Crime Code (UCR) categorization of CTC offenses utilized by the Federal Bureau of Investigation [42] that helps increase familiarity with the system (*R4*).

4.2 System Design

Our system consists of two main components, a server back-end for processing and computation, and a client front-end composed of our interactive mobile visual analytics system. The server back-end consists of a database that enables querying and provides data to the client. The data going into the server undergoes a pre-processing and data cleaning stage so it becomes ingestible to our client system. The front-end consists of the mobile device that provides a user interface for the visualization, exploration, and analysis of the spatiotemporal public safety dataset. The exploration and analysis of data is done per user on his/her device and our end users have indicated that it will be advantageous to have the ability to share this visualization or data exploration state with another user. However, since this is not in our initial list of requirements (Section 3.1), we leave this for future work.

4.3 Geospatial Displays

Our visual analytics system provides multiple views to visualize the spatial component of the datasets. We allow users to plot the incidents as points on the map that are color coded [10] to represent the different parameters of the datasets (e.g., agencies responding to the incident, offense type). The map has been dimmed so as to distinguish these color-coded incident points from the map colors. The radius scaling of the points is dependent on the zoom level. Moreover, in order to tackle the issue of over-plotting the incidents on the map, we provide interaction methods where the users can zoom in and tap on incidents and drill down to his or her level of interest. A better approach in dealing with the over-plotting issue is to show the aggregate sum of the overlapping incidents on the map at different zoom levels, and provide interaction techniques to show details on demand. We leave this as future work.

Furthermore, we utilize a kernel density estimation technique [25] to allow a quick exploration of the incidents on the map and to identify hotspots. The system also allows users to overlay different layers on the map (e.g., law beats, census tracts, bus routes) [44] and allows them to place custom placemarks. The users can also overlay driving and walking routes on the map, enabling them to visualize the CTC spatial distributions along their intended routes. An example of this has been shown in Figure 2(a).

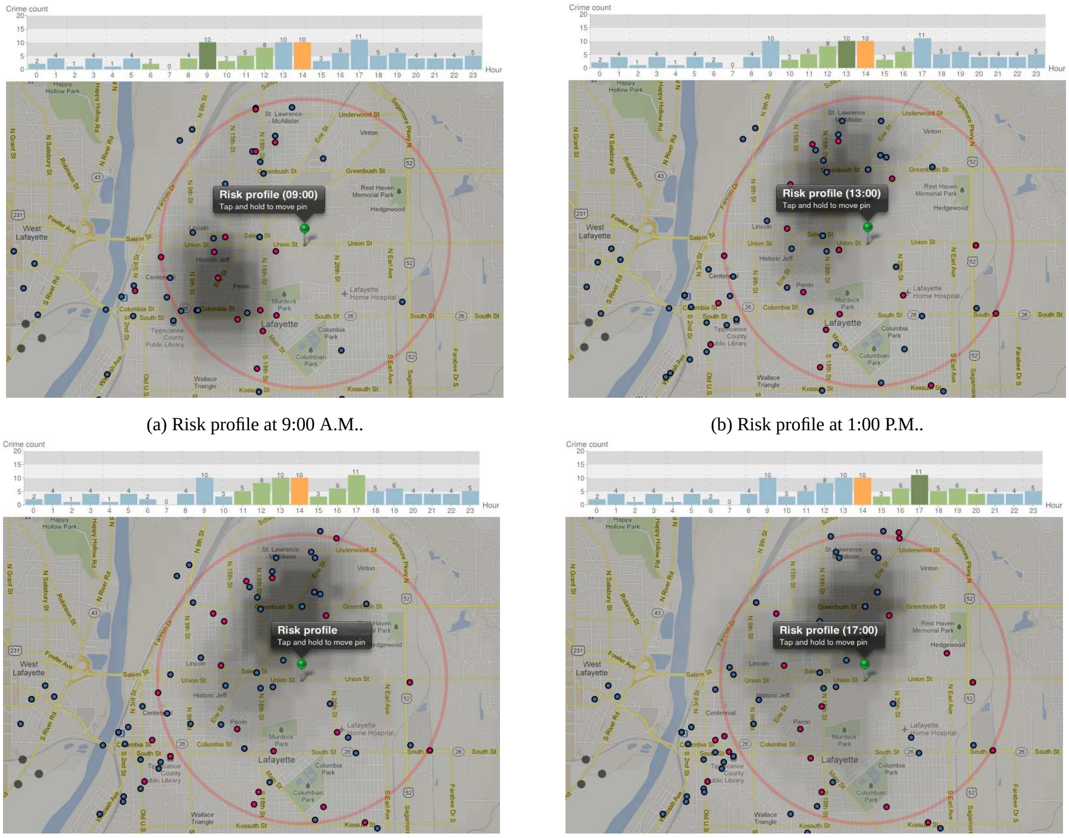
Furthermore, as is the case with most multivariate datasets, the CTC dataset is often incomplete. For example, many of the incidents do not contain valid geolocation data, causing uncertainty in the analysis process. In order to account for the uncertainty caused by this incompleteness in the dataset, we provide the ratio of correct incidents as a percentage value to show the accuracy of the visualization. This becomes important for users to accurately extract information from their dataset [22].

4.4 Temporal Displays and Analysis

Our system provides users with three temporal displays that allow them to visualize the temporal distribution of their datasets. We provide a time series display that presents the distribution of the incidents over time as a line graph, a calendar view visualization that lays the temporal data in the format of a calendar and a clock view that visualizes the hourly distribution of incidents.

4.4.1 Time Series View

The system allows users to simultaneously select multiple offenses and displays them as time series line graphs highlighting the trends between multiple datasets (Figure 2(b)). Furthermore, we provide



(a) Risk profile at 9:00 A.M..

(b) Risk profile at 1:00 P.M..

(c) Risk profile at the user's current time (2:00 P.M.).

(d) Risk profile at 5:00 P.M..

Figure 3: Risk profile visualizations at different times of day. The selected hour is shown by the dark green colored histogram bin, and the current time is shown as the orange colored bin. The ± 3 window from the current selected hour are shown as the green colored histogram bins, and the rest of the histogram bins is colored as blue.

users with several temporal aggregation options to aggregate their datasets. For example, users may choose to aggregate the incidents by day, week, month or year, and visualize the results dynamically. We further note that the time series display is interactive, allowing users to touch the screen to get the incident count at any particular time. A time series tape measure tool [26] in the graph view allows users to determine the temporal distance between any two points on the graph. We also provide users with tools that allow them to accurately model the data using an Exponentially Weighted Moving Average (EWMA) control chart for event prediction [26].

4.4.2 Calendar View

We adopt the calendar view visualization developed by van Wijk and Selow [43] to provide a temporal overview of the data in the format of a calendar, allowing users to visualize the data over time. Each date entry is colored on a sequential color scale that is based on the overall yearly trend to show the relative count of incidents for each day with respect to the maximum daily count over that calendar year.

To account for the smaller screen space of mobile devices (*C4*), we provide an overview+detail view. This is shown in Figure 2(c), where the left portion of the calendar view shows the weekly overview of the entire calendar. The overview display draws the individual rows based on the selected aggregation level (e.g., week, month) and are colored on a sequential color scale to reflect the weekly count of incidents. Users may tap on any portion of the calendar overview, updating the calendar view visualization dynamically to the position touched by the user. The overview+detail calendar view allows users to quickly identify weeks of high activity, and provides an easy way to scroll to them.

4.4.3 Clock View

In order to visualize the hourly distribution of the CTC incidents, we implement a clock view (Figure 2(d)) that organizes the data in the format of a clock. The clock view is a radial layout divided into 24 slices that are colored on a sequential color scale [10] to reflect the number of incidents that occur during each hour of a day.

As is the case with geospatial data (Section 4.3), many of the incidents do not contain a valid time field, causing uncertainty in the analysis process. Thus, we use the same method of displaying uncertainty for geospatial data in this domain, by showing the accuracy of the clock view visualization.

4.5 Risk Profile

The risk profile visualization shows the spatial and temporal distribution of incidents with respect to the current location and time of the user.

Our system utilizes the GPS feature of the mobile device and factors in the geospatial location of the user, the current time, and the historic CTC incidents occurring within their neighborhoods to provide estimates of CTC activity in their surroundings. These provide users with an overview of all the incidents and allows them to increase their level of situational awareness of the safety risks involved in their surroundings. Now, in order to show the spatial distribution of historic incidents, we utilize the map view and plot the incidents as points on the map. When users enable the risk profile feature, the system shows the current location of the user as a green colored pin on the map, and draws a circle (of a user-controlled radius) around their current location. The system then performs a query to the server and acquires all incidents that occur within this circle within a ± 3 hour offset (adjustable by the user)

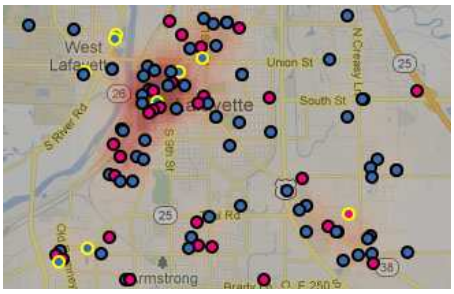


Figure 4: Incidents with nearby localized high-frequency activity are highlighted in yellow to alert users of areas with suspicious criminal activity.

with respect to the current time, for a date range specified by the user. The resulting incidents are then displayed as points on the map. Also, the temporal distribution of all incidents falling within the circle is shown in an interactive bar graph (Figure 3a (top)). We highlight the hours on this graph to reflect the hours on which the incidents are being displayed. Note that in addition to visualizing the risk profile for the current location and time, users may also choose to generate risk profiles for any desired spatial locations (by dragging the pin provided on the map) and for any hour of the day (by selecting a time by tapping on the risk profile time series graph (Figure 3a (top))). The users can then get a geotemporal overview of risk at any location and time.

In order to show which incidents have happened nearer in *time* (with respect to the current time of day), we modify the kernel density estimated heatmap (as described in Section 4.3) to encode the temporal distance from the current time. So in this case, the heatmap gives more weight to those incidents that fall closer to the current time within the ± 3 hour window, than to those that are farther away from the current time. The hotspots that so emerge provide an estimate of those incidents that happen closest in time with respect to the current time. An example of this approach is shown in Figure 3, where the user is visualizing all offenses against person and property for the month of February 2013. We can see hotspots emerging in different locations that show the distribution of incidents that happened closest to the current selected time.

4.6 Hotspot Alert

Our system also provides a feature to help users identify unusual localized high-frequency patterns of crimes and identify crime hotspot locations. Each data entry in the database is checked for other crimes with similar properties (defined by the user). This is done within a 200 meter block radius of the incident location, and for a 14 day period that extends from the day the incident occurred backwards in time. The system then highlights the incidents with the most number of similar incidents within the space-time window (Figure 4) which is updated dynamically as new data is entered into the database by the user. This alerts law enforcement officials of higher probability regions with nearby localized suspicious criminal activity and allows for more effective resource allocation and patrol planning.

4.7 Chemical Plume Modeling

Our system also provides a dynamic chemical plume modeling tool that provides law enforcement officers and first responders with better situational awareness in emergency situations resulting from chemical releases. Our system uses the ALOHA (Areal Locations of Hazardous Atmospheres) [1] software for chemical dispersion modeling and generating threat zones to assess the potential hazards caused by chemical releases. ALOHA is part of the CAMEO software suite [11] and can be used as a standalone desktop program.

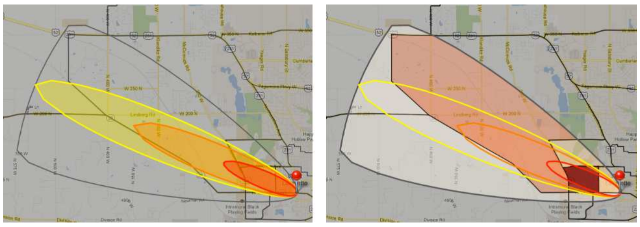


Figure 5: Plume visualization. (left) The plume visualization displaying the different levels of danger zones. (right) The plume visualization showing census tracts colored on a sequential color scale to encode the number of people affected in each census tract, with respect to the maximum people affected in any tract.

In the case of a hazardous chemical release, our system can display the threat zones (plume) as a geospatial visualization. Each threat zone defines an area where the hazard level exceeds some 'Levels of Concern' (LOC) [2]. The concentration of chemicals is measured in ppm (parts per million) and each LOC specifies an area with a certain range of the released chemical concentrations in ppm. The innermost zone shows the area of most hazard and the outer zone shows the area of least hazard. The number of zones shown on the map can be changed by changing the number of LOCs, but is set to three LOCs by default [2].

The threat zones are plotted on top of a geographic map to help first responders quickly identify the regions under the most threat and also the safest roads for travel and evacuation. The threat zones are dynamic in nature due to changing weather conditions, and their visualization on the mobile system can be updated regularly by the user. Our system allows two types of plume threat zone visualizations to be shown. Figure 5 (left) shows the first visualization where the plume is visualized as three threat zones, colored red, orange and yellow to encode the levels of danger from most danger to least danger. The visualization also takes into account the changing weather conditions and shows the plume model confidence interval, represented by the outermost threat zone boundary (dark outline). By default, only the confidence line of the outermost threat zone is shown, but the user can also choose to show confidence lines for each individual threat zone.

In the second visualization (Figure 5 (right)), we display color-coded census tracts to show the distribution of people affected by the chemical plume in addition to the plume LOC visualization. For the color encoding, we first calculate the ratio of the census tract area covered by the plume. By assuming uniform population distribution, we calculate the expected number of people affected by the chemical release in each census tract by multiplying this ratio with the census population data. We take the number of people affected in each census tract and normalize this number by the maximum number of people affected in any tract. This obtained value is used to pick a color from a sequential color scale to provide information about the census tracts that have larger percentages of people in danger due to the chemical release. Detailed statistics of the affected people can also be shown.

4.8 Implementation Notes

Our mobile system front-end has been developed for the iPad/iPhone environment on the iOS platform. The system requires iOS version 5.0 onwards and is developed in the Objective-C environment using XCode 4. The PROJ.4 Cartographic Projections Library [35] is used to switch between map projection systems and the Google Maps library is used for routing.

On the back-end of our server-client architecture, the database is managed by MySQL that enables data querying and the web service that handles data requests by the client uses PHP. Data is transmitted securely (*C5*) using HTTP over SSL/TLS in XML or plain text format to keep the data format simple and generic for other uses.

5 User Evaluation

In this section, we provide user feedback of our mobile visual analytics law enforcement system from domain experts from our local law enforcement agencies. For the purpose of evaluating our system, we formed a focus group of 15 domain experts consisting of several police departments in our local county as well as the county legal offices. We deployed our mobile system to this group in December 2012 and have made continuous modifications to the system based on their responses and feedback obtained from our meetings which include several demonstrations, structured interview questionnaires, and informal in-person discussions. Here, we report some of the group's responses over the past 9 months.

We have received generally very positive feedback from this group. At a high level, officers, especially the chief of police in our local community, saw great value and potential of the system for certain daily tasks. He cited one use of this system to increase public awareness of their safety from the criminal activities that occur in their surroundings during safety campaigns. He also mentioned its use to visualize the impacts of active crime prevention actions (e.g., resource allocation for patrol, public safety campaigns).

At another level, the shift supervisor responsible for overseeing the patrol officer assignments during their shift periods and communicating information of the previous shifts to the incoming officers viewed the application as a major improvement to their existing tools used for briefings and roll call (e.g., print outs of incident reports from the previous 24 hour period). The features within our system that allow the display of the heat map of incidents displayed provided an added level of focus for incident location. The feedback provided by the supervisor indicated that they utilized the temporal reporting features in conjunction with geospatial features to assist in resource allocation planning. They also found the convenience of having a mobile version useful for their roll call briefings that allows them to look at the past incidents and have discussions outside of the office space for instance while having coffee in the lounge.

Patrol officers saw the value of using the system while on the field to get CTC incidents data in a visual form to have an increased situation awareness. Furthermore, the officers particularly liked the risk profile feature that provides the regions with historically higher incident levels based on the patrol officers current position and time. They indicated that this feature was especially useful as it factored in the current time-of-day information while they were patrolling their area of responsibility. The Mobile Computer Terminal (MCT) systems in their patrol cars are currently more geared towards reactive policing for reacting to an emergent situation, and as such, our application provides them with tools that enable proactive policing. The officers, however, also indicated that our system should be better integrated with the functions provided by their MCTs (e.g., dispatch calls, ability to enter detailed reports to be stored directly in their database) for a more effective tool. They also indicated a need for voice controlled commands for performing common functions.

During discussions with law enforcement personnel, additional information would be useful to officers responding to incidents (e.g., protective orders, non-contact orders). However, this information does not currently reside within their systems and, as such, the officers do not get access to such data while responding to incidents. We plan on incorporating these datasets in our system to assist the law enforcement personnel with operational decisions when responding to service calls.

At the role level of detectives and crime analysts, the usage patterns begin to shift more towards the predictive end of the spectrum as well as an increased usage of the temporal reporting features. Detectives are responsible for, among other things, solving crimes by, for example, investigating crime patterns; whereas, crime analysts provide insights and analysis into patterns and trends in crime to their police departments. Existing analysis tools tend toward a list generating, selection/filtering tool. Geospatial mapping also seems to appear to be prominently used at the present time as an analysis tool for performing hotspot analysis. The overall graphical user interface of our system looks promising for this role because of the ease of use and the widely known mobile application selection, zoom, and positioning conventions. One feature that appears to be the most promising is the ability to dynamically create regions or utilize shape files for geographic boundary definition. These features allow the crime analyst and/or detective to zero in on specific geographic areas of interest, like neighborhoods or law beats, without having to manually sort through data. These features also assist in generating historical reports for use in detailed crime analysis or investigation. The detective/crime analyst also found the selection capability within the calendar tool useful for seasonal crime analysis.

From our engagements, an intelligence analyst responsible for providing intelligence and planning for strategic, operational or tactical situations also saw value in the system for his day-to-day tasks. He particularly liked the ability of the system to apply any desired filters on-the-fly in a visual interface in order to narrow down his investigative analysis and to observe any spatial or temporal patterns. He was also interested in the crime monitoring process with the system and the potential to quickly identify incidents that were viewable by security cameras and pull up live and historical feeds by those cameras. Additionally, he suggested adding a layer of surveillance camera locations along with their range and angle of view information in the system for use in identifying incidents that may have been captured by any of the cameras for investigative purposes.

6 Conclusions and Future Work

In this paper, we have presented our mobile visual analytics system that has been designed to equip law enforcement personnel and, in the future, citizens with effective situation awareness and risk assessment tools. Our current work demonstrates the benefits of visual analytics in the mobile domain, and shows the effectiveness of providing users with on-the-go tools that allow them to make effective decisions. We have learned that the use of a mobile risk assessment system differs slightly in providing real-time situation awareness from a full, thorough analysis of CTC incidents with a full-fledged system on a desktop. From our interaction with our end users, we know that they do not have the time to tinker with a technology: it has to just work. Also with law enforcement agencies, they are trained to handle risky situations and would not rely on the system to gauge risk and determine if backup is needed. The use of the system is also limited in tactical situations where attention in certain actions takes precedence (e.g., focusing on the road while driving). In this case, a technology like speech recognition would significantly help but this remains a research direction we have not yet explored. Finally, as has been shown in this paper, we argue that there is great potential for the use of mobile visual analytics solutions to serve multiple role levels in the law enforcement and other related domains.

Future work includes adding advanced analytical and predictive capabilities into the system. Furthermore, we plan on incorporating image-based glyphs to represent the incidents on the map for easier identification of the charges associated with the incidents. We also plan on enhancing our routing methodology to factor in the risk and other parameters in order to allow users to plan safer routes. In addition, we think that incorporating multiple datasets (e.g., census data, street light locations, court records, weather) in the system would be an interesting research direction to explore the correlations between CTC incidents and other datasets. We also plan on modifying the kernel density estimation technique to further incorporate road network information to factor in for incident types that are road bound (e.g., traffic accidents). Finally, we plan on investigating porting the system to other mobile platforms (e.g., Android, Windows RT).

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